LC 1078

NBS METRIC INFORMATION

THE METRIC SYSTEM OF MEASUREMENT (SI)

FEDERAL REGISTER NOTICE
of
DECEMBER 10, 1976

LC1078
Dec. 1976

This NBS Letter Circular reproduces the Federal Register notice that interprets and modifies the International System of Units (SI), the Modernized Metric System, for the United States. This notice supersedes a similar notice dated June 19, 1975.

Also included is a chart that shows the relationships of all the SI units to which names have been assigned.

U.S. DEPARTMENT OF COMMERCE/National Bureau of Standards Washington, D.C. 20234

This chart shows graphically how the 17 SI derived units with special names listed in Table 2 of the Federal Register Notice, reprinted on page 4, are derived in a coherent manner from the base and supplementary units. In the first column the symbols of the base and supplementary units are shown in rectangles, with the name of the unit shown toward the upper left of the rectangle and the name of the quantity (measurable attribute) shown below the rectangle. In the third column the symbols of the derived units with special names are shown in solid circles, with the name of the unit shown toward the upper left of the circle, the name of the quantity shown below the circle, and an expression of the derived unit in terms of other units shown toward the upper right. In the second column are shown those derived units without special names that are used in the derivation of the derived units with special names. In the chart the derivation of each unit is indicated by arrows bringing in numerator factors (solid lines) and denominator factors (broken lines).

The degree Celsius, shown on the chart in a broken-line rectangle, is a special name for the kelvin, for use in expressing Celsius temperatures or temperature intervals. Where it is used to express temperature intervals, it is equal to the kelvin, as shown on the chart, with the symbol K toward the upper right of the °C circle; where it is used to express Celsius temperatures, the equation below "CELSIUS TEMPERATURE" relates Celsius temperature ($t_{°C}$) to thermodynamic temperature (T_K).

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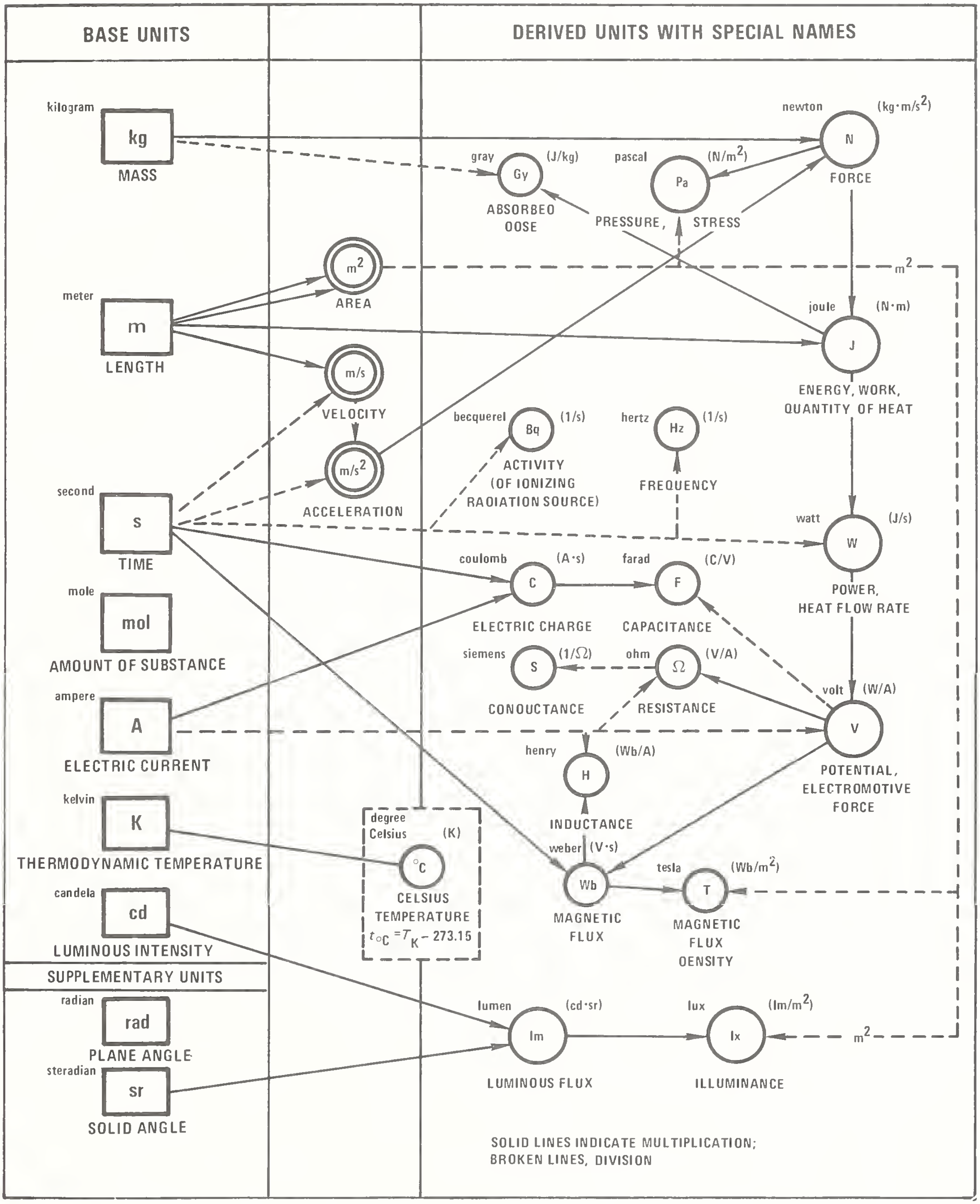
RELATIONSHIPS OF SI UNITS WITH NAMES



Office of the Secretary

THE METRIC SYSTEM OF MEASUREMENT

Interpretation and Modification of the International System of Units for the United States

Section 3 of Pub. L. 94–168, the Metric Conversion Act of 1975, declares that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States. Section 403 of Pub. L. 93–380, the Education Amendments of 1974, states the policy of the United States to encourage educational agencies and institutions to prepare students to use the metric system of measurement as part of the regular education program. Under both these acts, the "metric system of measurement" is defined as the International System of Units as established by the General Conference of Weights and Measures in 1960 and interpreted or modified for the United States by the Secretary of Commerce (subsec. 4(4), Pub. L. 94–168; subsec. 403(a) (3), Pub. L. 93–380) The Secretary has delegated his authority under these subsections to the Assistant Secretary for Science and Technology. Accordingly, in implementation of this authority, the following tables and associated materials set forth the interpretation and modification of the International System of Units (hereinafter "SI") for the United States.

This notice supersedes the notice of the National Bureau of Standards published in the FEDERAL REGISTER of June 19, 1975 (40 FR 25837).

The SI is constructed from seven base units for independent quantities plus two supplementary units for plane angle and solid angle, listed in Table 1.

TABLE 1.—*SI base and supplementary units*

Quantity	Name	Symbol
SI base units:		
length	meter	m
mass [1]	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature [2]	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd
SI supplementary units:		
plane angle	radian	rad
solid angle	steradian	sr

[1] "Weight" is the commonly used term for "mass."

[2] Wide use is made of "Celsius temperature" (symbol t) defined by

$$t=T-T_0$$

where T is the thermodynamic temperature, expressed in kelvins, and T_0=273.15 K by definition. The unit "degree Celsius" is thus equal to the unit "kelvin," but the degree Celsius (symbol °C) is a special name used instead of kelvin for expressing Celsius temperature. A temperature interval or a Celsius temperature difference may be expressed in degrees Celsius as well as in kelvins.

Units for all other quantities are derived from these nine units. In Table 2 are listed 17 SI derived units with special names which were derived from the base and supplementary units in a coherent manner, which means, in brief, that they are expressed as products and ratios of the nine base and supplementary units without numerical factors.

TABLE 2.—*SI derived units with special names*

Quantity	SI unit: Name	Symbol	Expression in terms of other units
frequency	hertz	Hz	s^{-1}
force	newton	N	$kg \cdot m/s^2$
pressure, stress	pascal	Pa	N/m^2
energy, work, quantity of heat.	joule	J	$N \cdot m$
power, radiant flux	watt	W	J/s
quantity of electricity, electric charge.	coulomb	C	$A \cdot s$
electric potential, potential difference, electromotive force.	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
conductance	siemens	S	A/V
magnetic flux	weber	Wb	$V \cdot s$
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	$cd \cdot sr$
illuminance	lux	lx	lm/m^2
activity (of ionizing radiation source).	becquerel	Bq	s^{-1}
absorbed dose	gray	Gy	J/kg

All other SI derived units, such as those in tables 3 and 4, are similarly derived in a coherent manner from the 26 base, supplementary, and special-name SI units.

TABLE 3.—*Examples of SI derived units expressed in terms of base units*

Quantity	SI unit	Unit symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared.	m/s^2
wave number	1 per meter	m^{-1}
density, mass density.	kilogram per cubic meter.	kg/m^3
current density	ampere per square meter.	A/m^2
magnetic field strength.	ampere per meter	A/m
concentration (of amount of substance).	mole per cubic meter	mol/m^3
specific volume	cubic meter per kilogram.	m^3/kg
luminance	candela per square meter.	cd/m^2

TABLE 4.—*Examples of SI derived units expressed by means of special names*

Quantity	Name	Unit symbol
dynamic viscosity	pascal second	$Pa \cdot s$
moment of force	newton meter	$N \cdot m$
surface tension	newton per meter	N/m
power density, heat flux density, irradiance.	watt per square meter.	W/m^2
heat capacity, entropy.	joule per kelvin	J/K
specific heat capacity, specific entropy.	joule per kilogram kelvin.	$J/(kg \cdot K)$
specific energy	joule per kilogram	J/kg
thermal conductivity.	watt per meter kelvin.	$W/(m \cdot K)$
energy density	joule per cubic meter.	J/m^3
electric field strength	volt per meter	V/m
electric charge density.	coulomb per cubic meter.	C/m^3
electric flux density	coulomb per square meter.	C/m^2
permittivity	farad per meter	F/m
permeability	henry per meter	H/m
molar energy	joule per mole	J/mol
molar entropy, molar heat capacity.	joule per mole kelvin.	$J/(mol \cdot K)$

For use with the SI units there is a set of 16 prefixes (see table 5) to form multiples and submultiples of these units. It is important to note that the kilogram is the only SI unit with a prefix. Because double prefixes are not to be used, the prefixes of table 5, in the case of mass, are to be used with gram (symbol g) and not with kilogram (symbol kg).

TABLE 5.—*SI prefixes*

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Certain units which are not part of the SI are used so widely that it is impractical to abandon them. The units that are accepted for continued use in the United States with the International System are listed in table 6.

TABLE 6.—*Units in use with the international system*

Name	Symbol	Value in SI unit
minute (time)	min	1 min=60 s
hour	h	1 h=60 min=3 600 s
day	d	1 d=24 h=86 400 s
degree (angle)	°	1°=(π/180) rad
minute (angle)	′	1′=(1/60)°=(π/10 800) rad
second (angle)	″	1″=(1/60)′ =(π/648 000) rad
liter	L*	1 L=1 $dm^3=10^{-3}$ m^3
metric ton	t	1 t=10^3 kg
hectare (land area)	ha	1 ha=10^4 m^2

*The international symbol for liter is the lowercase "l", which can easily be confused with the numeral "1". Accordingly, the symbol "L" is recommended for United States use.

In those cases where their usage is already well established, the use, for a limited time, of the units in table 7 is accepted, subject to future review.

TABLE 7.—*Units to be used for a limited time*

nautical mile	angstrom	gal [1]
knot	barn	curie
standard atmosphere	bar	roentgen
		rad [2]

[1] Unit of acceleration.

[2] Unit of absorbed dose.

Metric units, symbols, and terms that are not in accordance with the foregoing Interpretation and Modification are no longer accepted for continued use in the United States with the International System of Units. Accordingly, the following units and terms listed in the table of metric units in section 2 of the act of July 28, 1866, that legalized the metric system of weights and measures in the United States, are no longer accepted for use in the United States:

myriameter
stere
millier or tonneau
quintal
myriagram
kilo (for kilogram)

For more information regarding the International System of Units, contact the Office of Technical Publications, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C. 20234.

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[FR Doc.76-36414 Filed 12-9-76;8:45 am]